Dynamic Analysis of Photovoltaic/Wind Turbine Hybrid Micro-grid Energy System

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We certify that the thesis is entitled "**Dynamic Analysis of Photovoltaic/Wind Turbine Hybrid Micro-grid Energy System**" written by **Hai Jing**. We have examined the final copy of this thesis and that in our opinion; it is fully adequate in terms of scope and quality for the awarding the degree of Masters of Engineering in Electrical Engineering. We herewith recommend that it be accepted in fulfilment of the requirements for the degree of Masters of Engineering in specializing in the Electrical Engineering.

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LIST OF ABBREVIATIONS

DG	Distributed Generation
DN	Distribution Network
MG	Micro-Grid
RES	Renewable Energy Sources
CHP	Cogeneration Systems
SMES	Superconducting Magnetic Energy Storage
PCC	Point of Common Coupling
MGCC	Micro-Grid Central Controller
PV	Photo-Voltaic
DC	Direct Current
AC	Alternative Current
WECS	Wind Energy Conversion System
MPPT	Maximum Power Point Tracking
CMI	Current Mode Inverter
VMI	Voltage Mode Inverter
HOMER	Hybrid Optimization Model for Electric Renewable
MS	Micro Sources
P&O	Perturb & Observation
IC	Incremental Conductance

ABSTRACT

Connecting the electric grid to rural and remote areas is very uneconomical to carry out. Moreover, the utility network is not designed to fulfill the growing needs of the population and may be destabilized by new consumers. Therefore, it is more economical to electrify those areas with a micro-grid by means of existing renewable energy sources available locally. The micro-grid configuration represents the energy distribution architecture from the producing sites to consumers and eventually the interconnection between several sites and some consumers. The study of such a matrix configuration is realized using simulation tools and has to be considered from the system level with economical matters in addition to the technical aspects. As for the optimization of a hybrid micro-grid system, several models have been built to simulate and optimize hybrid systems. In this work, a quasi-dynamic model of hybrid micro-grid energy system was built use HOMER software based on a typical local household load. The optimized result was obtained under local solar/wind resources data and renewable fraction constrains. Malaysia tropical weather which has abundant solar irradiation and rich wind resource which is suitable to build a renewable energy system for most the under electrified area. According to the structure and the voltage output characteristics of the photo-voltaic array and solar panels, the framework the PV energy system simulation model is carried out. In this model, the perturb and observation method is applied to track the maximum point of the PV array power. Then the oriented vector control methods are implemented to achieve the dual closed-loop control for DC voltage and AC current, and connected to the utility grid by a three-phase PWM voltage inverter. In a real environment, the PV array temperature and solar irradiation are changing, and this has to be considered in the simulation. Since the PV energy system cannot store the excess energy, the charging and discharging characteristics of the battery are also studied and simulated. The battery storage can contribute to the stability of the PV energy system. The dynamic model of the proposed hybrid micro-grid was built in Matlab Simulink software, simulation on both grid connected operation and stand-alone operations are conducted. The series of data gained from this simulation can be a support for the real practical system, which have certain practical value.

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ABSTRAK

Menyambung grid elektrik ke kawasan luar bandar dan pedalaman adalah sangat tidak ekonomi untuk menjalankan. Tambahan pula, rangkaian utiliti tidak direka untuk memenuhi keperluan penduduk yang semakin meningkat dan boleh tidak stabil oleh pengguna baru. Oleh itu, ia lebih menjimatkan elektrik kawasan-kawasan dengan grid mikro dengan menggunakan sumber tenaga yang sedia ada yang boleh diperbaharui terdapat di dalam negara. Konfigurasi mikro-grid mewakili agihan seni bina tenaga dari laman web pengeluar kepada pengguna dan akhirnya perhubungan di antara beberapa tempat dan beberapa pengguna.Kajian konfigurasi matriks direalisasikan dengan menggunakan alat simulasi dan dipertimbangkan dari peringkat sistem dengan perkara-perkara yang menjimatkan di samping aspek teknikal. Sebagai untuk pengoptimuman sistem hibrid mikro grid, beberapa model telah dibina untuk simulasi dan mengoptimumkan sistem hibrid. Dalam kajian ini, model seakan-akan dinamik hibrid mikro-grid tenaga sistem ini dibina menggunakan perisian Homer yang berdasarkan beban isi rumah tempatan yang tipikal. Hasil yang optimal telah diperolehi di bawah sumber solar / angin data tempatan dan pecahan boleh diperbaharui kekangan. Cuaca tropika Malaysia yang mempunyai penyinaran yang banyak solar dan angin sumber kaya yang sesuai untuk membina sebuah sistem tenaga boleh diperbaharui bagi kebanyakan di bawah kawasan elektrik.Menurut struktur dan ciri-ciri voltan keluaran array foto-voltan dan panel solar, rangka kerja tenaga PV sistem simulasi model yang dijalankan. Dalam model ini, kaedah mencemaskan dan pemerhatian digunakan untuk mengesan titik maksimum kuasa pelbagai PV. Kemudian berorientasikan kaedah kawalan vektor dilaksanakan untuk mencapai dual kawalan gelung tertutup bagi DC voltan dan arus AC, dan disambungkan ke grid utiliti oleh penyongsang tiga fasa voltan PWM. Dalam persekitaran yang sebenar, suhu PV array dan penyinaran suria berubah, dan ini akan dipertimbangkan dalam penyelakuan. Sejak sistem PV tenaga tidak boleh menyimpan tenaga yang berlebihan, ciri-ciri mengecas dan menyahcas bateri juga dikaji dan simulasi. Penyimpanan bateri boleh menyumbang kepada kestabilan sistem tenaga PV. Model dinamik yang dicadangkan hibrid mikro-grid dibina di Matlab Simulink perisian, simulasi kedua-dua operasi grid yang berkaitan dan operasi bersendirian dijalankan. Siri data yang diperolehi daripada simulasi ini boleh menjadi sokongan untuk sistem sebenar yang praktikal, yang mempunyai nilai praktikal yang tertentu.

REFERENCES

Achaibou, N. Haddadi, M. and Malek, A. 2008. Lead acid batteries simulation including experimental validation. *Journal of Power Sources*， **185:** 1484-1491.

Ahmed, N. 2008. Computational modeling and polarization characteristics of proton exchange membrane fuel cell with evaluation of its interface systems. *EPE Journal European Power Electronics and Drives Journal*， **18:** 32-41.

Ahmed, N.Miyatake, M. and Al-Othman, A. 2008. Power fluctuations suppression of stand-alone hybrid generation combining solar photovoltaic/wind turbine and fuel cell systems. *Energy Conversion and Management*， **49:** 2711-2719.

Ai, B. Yang, H. Shen, H. and Liao, X. 2003. Computer-aided design of PV/wind hybrid system. *Renewable Energy,***28:** 1491-1512.

Azhari, A. Sopian, K. Zaharim, A. and Al Ghoul, M. 2008. A new approach for predicting solar radiation in tropical environment using satellite images - case study of Malaysia. *WSEAS Transactions on Environment and Development,* **4:** 373-378.

Balaguer, I. Lei, Q. Yang, S. Supatti, U. and Zheng, F. 2011. Control for grid-connected and intentional islanding operations of distributed power generation. *IEEE Transactions on Industrial Electronics,* **58:** 147-157.

Balaguer, I. Supatti, U. Lei, Q. Choi, N. S. and Peng, F. 2008. Intelligent control for intentional islanding operation of microgrids. *Sustainable Energy Technologies, IEEE International Conference on ICSET,* **55:** 898-903.

Bana Sharifian, M. Mohamadrezapour, Y. Hosseinpour, M. and Torabzade, S. 2009. Single-stage grid connected photovoltaic system with reactive power control and adaptive predictive current controller. *Journal of Applied Sciences,* **9:** 1503-1509.

Barker, P. 2002. Ultra capacitors for use in power quality and distributed resource applications. *IEEE Power Engineering Society Summer Meeting,* **1:** 97-316.

Barnes, M. Kondoh, J. Asano, H. Oyarzabal, J. Ventakaramanan, G. Lasseter, R. Hatziargyriou, N. and Green, T. 2007. Real-world microgrids-an overview. *IEEE International Conference on System of Systems Engineering,* **71:** 1-8.

Belfkira, R. Nichita, C. Reghem, P. and Barakat, G. 2008. Modeling and optimal sizing of hybrid renewable energy system. *Power Electronics and Motion Control Conference, EPE-PEMC,* **99:** 1834-1839.

Bernal-Agust ń, J. and Dufo-L ópez, R. 2009. Simulation and optimization of stand-alone hybrid renewable energy systems. *Renewable and Sustainable Energy Reviews,* **13:** 2111-2118.

Beucher, O. and Weeks, M. 2008. *Introduction to Matlab & Simulink: a project approach infinity science series engineering series,* Infinity Science Press.

Breeze, P. 2005. *Power generation technologies.* Newnes.

Bueno, C. and Carta, C. C. 2005. Technical-economic analysis of wind-powered pumped hydro storage systems part II model application to the island of EL Hierro. *Solar Energy,* **78:** 396-405.

Burke, A. 2000. Ultra capacitors why how and where is the technology. *Journal of Power Sources,* **91:** 37-50.

Chang, T. J. and Tu, Y. L. 2007. Evaluation of monthly capacity factor of WECS using chronological and probabilistic wind speed data a case study of Taiwan. *Renewable Energy,* **32:** 1999-2010.

Chen, W. Shen, H. Shu, B. Qin, H. and Deng, T. 2007. Evaluation of performance of MPPT devices in PV systems with storage batteries. *Renewable energy,* **32:** 1611-1611.

Chicco, G. and Mancarella, P. 2009. Distributed multi-generation a comprehensive view. *Renewable and Sustainable Energy Reviews,* **13:** 535-551.

Chuah, D. and Lee, S. 1981. Solar radiation estimates in Malaysia. *Solar Energy,* **26:** 33-40.

Chuah, D. G. S. and Lee, S. L. 1982. Solar radiation in peninsular Malaysia—statistical presentations. *Energy Conversion and Management,* **22:** 71-84.

Dakkak, M. Hirata, A. Muhida, R. and Kawasaki, Z. 2003. Operation strategy of residential centralized photovoltaic system in remote areas, *Renewable Energy,* **28:** 997-1012.

Dayan, E. 2006. Wind energy in buildings power generation from wind in the urban environment - where it is needed most. *Refocus,* **7:** 33-34, 36, 38.

Diaf, S. Belhamel, M. Haddadi, M. and Louche, A. 2008. Technical and economic assessment of hybrid photovoltaic/wind system with battery storage in Corsica island. *Energy Policy,* **36:** 743-754.

Djamila, H.Ming, C. and Kumaresan, S. 2011. Estimation of exterior vertical daylight for the humid tropic of kota kinabalu city in east Malaysia. *Renewable Energy,* **36:** 9-15.

Duffie, J. A. and Beckman, W. A. 1980. *Solutions manual for solar engineering of thermal processes.* Solar Energy Laboratory, University of Wisconsin-Madison.

Eicker, U. and Knovel. 2003. *Solar technologies for buildings.* Wiley Online Library.

Exell, R. and Fook, C. T. 1986. The wind energy potential of Malaysia. *Solar Energy,* **36:** 281-289.

Faranda, R. and Leva, S. 2008. Energy comparison of MPPT techniques for PV systems. *WSEAS Transactions on Power Systems,* **3:** 446-455.

Faridah, M. 2011. http://www.met.gov.my/, klim@met.gov.my, 18, April, 2011.

Femia, N.; Petrone, G.; Spagnuolo, G.; Vitelli, M. 2005. Optimization of perturb and observe maximum power point tracking method. *Transactions on Power Electronics, IEEE,* **20:** 963-973.

Femia, N.Granozio, D. Petrone, G. Spagnuolo, G. and Vitelli, M. 2006. Optimized one-cycle control in photovoltaic grid connected applications. *IEEE Transactions on Aerospace and Electronic Systems,* **42:** 954-954.

Glover, J.Sarma, M. and Overbye, T. 2008. *Power system analysis and design.* Cengage Learning Press.

Gonz áez-Longatt, F. 2006. Model of photovoltaic module in Matlab. *II CIBELEC,* **2006:** 1-5.

Greenstream Publishing. 2011. Solar Irradiance - calculate the solar energy available on your site. http://solarelectricityhandbook.com/solar-irradiance.html (18 April 2011)

Haidar, A.John, P. and Shawal, M. 2010. Optimal configuration assessment of renewable energy in Malaysia. *Renewable Energy,* **36:** 881-888.

Hart, D. W. 1997. *Introduction to power electronics.* Prentice Hall Press.

Hatziargyriou, N. Asano, H. Iravani, R. and Marnay, C. 2007. Microgrids. *IEEE Power and Energy Magazine,* **5:** 78-94.

Heckttheuer, L.Krenzinger, A. and Prieb, C. 2002. Methodology for photovoltaic modules characterization and shading effects analysis. *Revista Brasileira de Ciencias Mecanicas Journal of the Brazilian Society of Mechanical Sciences,* **24:** 26-31.

Heier, S. and Waddington, R. 1998. *Grid integration of wind energy conversion systems.* Wiley.

Himri, Y. Boudghene Stambouli, C. Draoui, B. and Himri, S. 2008. Techno-economical study of hybrid power system for a remote village in Algeria. *Energy,* **33:** 1128-1136.

Hiskens, I. and Fleming, E. 2008. Control of inverter-connected sources in autonomous microgrids. *American Control Conference,* **53:** 586-590.

Hunter, R. and Elliot, G. 1994. *Wind-diesel systems: a guide to the technology and its implementation.* Cambridge University Press.

Hussin, M. Hamid, M. Zain, Z. and Rahman, R. 2010. An evaluation data of solar irradiation and dry bulb temperature at Subang under Malaysian climate. *IEEE Control and System Graduate Research Colloquium (ICSGRC),* **1:**55-60.

Ibrahim, H. Ilinca, A. and Perron, J. 2008. Energy storage systems-characteristics and comparisons. *Renewable and Sustainable Energy Reviews,* **12:** 1221-1250.

IEEE. 2003. IEEE standard for interconnecting distributed resources with electric power systems. 1-16.

IEEE. 2009. IEEE application guide for IEEE std. 1547, IEEE standard for interconnecting distributed resources with electric power systems. 1-207.

Jiayi, C. Chuanwen, J. and Rong, X. 2008. A review on distributed energy resources and microgrid. *Renewable and Sustainable Energy Reviews*, **12:** 2465-2476.

John, V. 2008. Higher order output filter design for grid connected power converters . *Fifteenth National Power Systems Conference (NPSC),* **22:**614-619.

Jonas K. and Oliver K. 2011. Windfinder - Wind & weather statistic Balok/Kuantan. http://www.windfinder.com/windstats/windstatistic_balok_kuantan.html (18 April 2011)

Juhari, Ab. R. Kamaruzzaman, S. Yusoff. A, Mohammad, A. A. Azami, Z. and Ibrahim. A. Optimization of PV-wind-hydro-diesel system by minimizing excess capacity. 2009. *European Journal of Scientific Research*, **25:** 663-671

Justus, C. Hargraves, W. and Yalcin, A. 1976. Nationwide assessment of potential output from wind-powered generators. *Journal of Applied Meteorology,* **15:** 673-678.

Kaldellis, J. 2007. An integrated model for performance simulation of hybrid wind-diesel systems. *Renewable Energy*, **32:** 1544-1564.

Kaldellis, J. H. 2009. *Technology of stand-alone and hybrid wind energy production and storage*. Woodhead.

Karatepe, E. Boztepe, M. and Colak, M. 2007. Development of a suitable model for characterizing photovoltaic arrays with shaded solar cells. *Solar Energy,* **81:** 977-992.

Kariniotakis, G. Soultanis, N. Tsouchnikas, A. Papathanasiou, S. and Hatziargyriou, N. 2005. Dynamic modeling of microgrids. *International Conference on Future Power Systems*, **47:** 1-7.

Katiraei, F. Mauch, K. and Dignard-Bailey, L. 2007. Integration of photovoltaic power systems in high-penetration clusters for distribution networks and mini-grids. *International Journal of Distributed Energy Resources,* **3:** 207-224.

Kaundinya, C. C. Balachandra, C. and Ravindranath, N. 2009. Grid-connected versus stand-alone energy systems for decentralized power-a review of literature. *Renewable and Sustainable Energy Reviews,* **13:** 2041-2050.

Khan, M. and Iqbal, M. 2005. Dynamic modeling and simulation of a small wind-fuel cell hybrid energy system. *Renewable Energy,* **30:** 421-439.

Khan, M. and Iqbal, M. 2005. Pre-feasibility study of stand-alone hybrid energy systems for applications in Newfoundland. *Renewable energy,* **30:** 835-854.

Kottas, T. Boutalis, Y. and Karlis, A. 2006. New maximum power point tracker for PV arrays using fuzzy controller in close cooperation with fuzzy cognitive networks. *IEEE Transactions on Energy Conversi,* **21:** 793-803.

Krause, P. C. Wasynczuk, O. and Sudhoff, S. D. 1995. *Analysis of electric machinery.* IEEE Press.

Kroposki, B. Lasseter, R. Ise, T. Morozumi, S. Papatlianassiou, S. and Hatziargyriou, N. 2008. Making microgrids work. *Power and Energy Magazine, IEEE,* **6:** 40-53.

Lau, K.Y. Yousof, M.F.M. Arshad, S.N.M. Anwari, M. and Yatim, H.M. 2010. Performance analysis of hybrid photovoltaic/diesel energy system under Malaysian conditions. *Energy,* **35:** 3245-3255

Lee, S. Kim, J. Lee, J. and Cho, B. 2008. State-of-charge and capacity estimation of lithium-ion battery using a new open-circuit voltage versus state-of-charge. *Journal of Power Sources,* **185:** 1367-1373.

Li, C. H. Zhu, X. J. Cao, G. Y. Sui, S. and Hu, M. R. 2009. Dynamic modeling and sizing optimization of stand-alone photovoltaic power systems using hybrid energy storage technology. *Renewable Energy,* **34:** 815-826.

Li, X.Song, Y. J. and Han, S. B. 2007. Study on power quality control in multiple renewable energy hybrid microgrid system. *Power Tech, IEEE Lausanne,* **25:** 2000-2005.

Mahlia, T. and Chan, P. 2010. Life cycle cost analysis of fuel cell based cogeneration system for residential application in Malaysia. *Renewable and Sustainable Energy Reviews,* **15:** 416-426

Manolakos, C. Papadakis, G. Papantonis, C. and Kyritsis, S. 2001. A simulation-optimization program for designing hybrid energy systems for supplying

electricity and fresh water through desalination to remote areas case study the merssini village donoussa island Aegean Sea Greece. *Energy,* **26:** 679-704.

Mao, H. 2000. Study on three-phase high-input-power-factor PWM-voltage-type reversible rectifiers and their control strategies. *Chinese, Ph. D. dissertation, Zhejiang Univ, Hangzhou, China.*

Mao, M. Q. Yu, S. J. and Su, J. H. 2005. Versatile Matlab simulation model for photovoltaic array with mppt function. *Xitong Fangzhen Xuebao Journal of System Simulation,* **17:** 1248-1251.

Mao, M. Su, J. H. Chang, L. C. Gu, R. Z. and Yu, Q. 2008. Controller for 1kW-5kW wind-solar hybrid generation systems. *Canadian Conference on Electrical and Computer Engineering,* **7:**1175 – 1178.

Middlebrook, R. 1988. Small-signal modeling of pulse-width modulated switched-mode power converters. *Proceedings of the IEEE,* **76:** 343-354.

Mohan, N. Undeland, T. M. and Robbins, W. P. 1995. *Power electronics: converters, applications, and design.* Wiley Press.

Mufti, M. Lone, S. Iqbal, S. Ahmad, M. and Ismail, M. 2009. Super-capacitor based energy storage system for improved load frequency control. *Electric Power Systems Research,* **79:** 226-233.

Nehrir, M. and Wang, C. 2009. *Modeling and control of fuel cells: distributed generation applications.* Wiley Press.

Nema, P. Nema, R. and Rangnekar, S. 2009. A current and future state of art development of hybrid energy system using wind and PV-solar a review. *Renewable and Sustainable Energy Reviews,* **13:** 2096-2103.

Nfah, E. Ngundam, J. and Tchinda, R. 2007. Modeling of solar/diesel/battery hybrid power systems for far-north Cameroon. *Renewable Energy,* **32:** 832-844.

Nguyen, K. 2007. Alternatives to grid extension for rural electrification decentralized renewable energy technologies in Vietnam. *Energy Policy,* **35:** 2579-2589.

Nikkhajoei, H. and Lasseter, R. 2007. Microgrid protection. *IEEE Power Engineering Society General Meeting,* **4:**1-6.

Nikos H. 2011. Microgrids. http://www.microgrids.eu/micro2000/index.php?page=deliverables (18 April 2011)

Notton, G. Muselli, M. Poggi, P. and Touché, A. 2001. Decentralized wind energy systems providing small electrical loads in remote areas. *International Journal of Energy Research,* **25:** 141-164.

Nouni, M. Mullick, S. and Kandpal, T. 2008. Providing electricity access to remote areas in India an approach towards identifying potential areas for decentralized electricity supply. *Renewable and Sustainable Energy Reviews,* **12:** 1187-1220.

Othman, M. 1993. Diurnal pattern of global solar radiation in the tropics: a case study in Malaysia. *Renewable energy,* **3:** 741-745.

Oyarzabal, J. Jimeno, J. Ruela, J. Engler, A. and Hardt, C. 2005. Agent based micro grid management system. *International Conference on Future Power Systems,* **56:** 1-6.

Pallabazzer, R. 1995. Evaluation of wind-generator potentiality. *Solar Energy,* **55:** 49-59.

Patel, M. R. 2006. *Wind and solar power systems: design, analysis, and operation mechanical engineering.* Taylor & Francis.

Pepermans, G. Driesen, J. Haeseldonckx, D. Belmans, R. and D'haeseleer, W. 2005. Distributed generation definition benefits and issues. *Energy Policy,* **33:** 787-798.

Poullikkas, C. 2007. Implementation of distributed generation technologies in isolated power systems. *Renewable and Sustainable Energy Reviews,* **11:** 30-56.

Pratt, R. Conner, C. Cooke, B. and Richman, E. 1993. Metered end-use consumption and load shapes from the ELCAP residential sample of existing homes in the pacific northwest. *Energy and Buildings,* **19:** 179-193.

Pudjianto, D. Strbac, G. Oberbeeke, V. Androutsos, A. Larrabe, Z. and Saraiva, J. 2005. Investigation of regulatory, commercial, economic and environmental issues in microgrids. *International Conference on Future Power Systems,* **32:** 1-6.

Ravindranath, P. 2002. Small wind turbines-unsung heroes of wind industry. *Refocus,* **3:** 30-36.

Rosell, J. and Ib áñez, M. 2006. Modeling power output in photovoltaic modules for outdoor operating conditions. *Energy Conversion and Management,* **47:** 2424-2430.

Rui, H. Steven, L. Ufuk, T. Chandy, K. and Christopher, C. 2011. Optimal design of hybrid energy system with PV/wind turbine/storage: A case study. *IEEE International Conference on Smart Grid Communications,* **7:**511-516.

Samo, K.Nik, W.Muzathik, A. and Ibrahim, M. 2010. Reference solar radiation year and some climatology aspects of east coast of west Malaysia. *American Journal of Engineering and Applied Sciences,* **3:** 293-299.

Sebastián, R. 2008. Smooth transition from wind only to wind diesel mode in an autonomous wind diesel system with a battery-based energy storage system. *Renewable Energy,* **33:** 454-466.

Singal, S.Varun and Singh, R. 2007. Rural electrification of a remote island by renewable energy sources. *Renewable Energy,* **32:** 2491-2501.

Singh, P.Singh, S.Lal, M. and Husain, M. 2008. Temperature dependence of IV characteristics and performance parameters of silicon solar cell. *Solar Energy Materials and Solar Cells,* **92:** 1611-1616.

Smith, G.Onions, P. and Infield, D. 2000. Predicting islanding operation of grid connected PV inverters. *IEEE Proceedings Electric Power Applications,* **147:** 1-6.

Sopian, K. and Othman, M. 1992. Estimates of monthly average daily global solar radiation in Malaysia. *Renewable energy,* **2:** 319-325.

Sopian, K. Fudholi, A. Ruslan, M. Sulaiman, M. Alghoul, M. Yahya, M. Amin, N. Haw, L. and Zaharim, A. 2009. Optimization of a stand-alone wind/PV hybrid system to provide electricity for a household in Malaysia. *Proceedings of the 4th IASME/WSEAS international conference on Energy & environment,* 435-438.

Sopian, K. Zaharim, A. Ali, Y. Nopiah, Z. Razak, J. and Muhammad, N. 2008. Optimal operational strategy for hybrid renewable energy system using genetic algorithms. *WSEAS Transactions on Mathematics,* **7:** 130-130.

Sun, X. Wu, W. Li, X. and Zhao, Q. 2002. A research on photovoltaic energy controlling system with maximum power point tracking. *Proceedings of the Power Conversion Conference,* **2:** 822-822.

Takano, K. Nozaki, K. Saito, Y. Negishi, A. Kato, K. and Yamaguchi, Y. 2000. Simulation study of electrical dynamic characteristics of lithium-ion battery. *Journal of Power Sources,* **90:** 214-223.

Texas Instruments .1998. Field Orientated Control of three-Phase AC-Motors. 073. Texas Instruments Europe February. http://www.ti.com/lit/an/bpra073/bpra073.pdf

Tsai, M. and Tsai, W. 1999. Analysis and design of three-phase ac-to-dc converters with high power factor and near-optimum feed forward. *IEEE Transactions on Industrial Electronics,* **46:** 535-543.

Twidell, J. and Weir, A. 2006. *Renewable energy resources.* Spon Press.

Underwood, C. Ramachandran, J. Giddings, R. and Alwan, Z. 2007. Renewable-energy clusters for remote communities. *Applied energy,* **84:** 579-598.

Uzunoglu, M. and Alam, M. 2007. Dynamic modeling design and simulation of a PEM fuel cell/ultra-capacitor hybrid system for vehicular applications. *Energy Conversion and Management,* **48:** 1544-1553.

Uzunoglu, M. Onar, O. and Alam, M. 2009. Modeling control and simulation of a PV/FC/UC based hybrid power generation system for stand-alone applications. *Renewable Energy,* **34:** 509-520.

Vander Vleuten, C. and Raven, R. 2006. Lock-in and change distributed generation in denmark in a long-term perspective. *Energy Policy,* **34:** 3739-3748.

Vegte, J. V. D. and Vegte, J. V. 1994. *Feedback control systems.* Prentice Hall.

Venu, C. 2009. Islanded operation of a distribution feeder with distributed generation. *Ph.D. dissertation, University of Nevada Las Vegas.*

Vosen, S. and Keller, J. 1999. Hybrid energy storage systems for stand-alone electric power systems optimization of system performance and cost through control strategies. *International Journal of Hydrogen Energy,* **24:** 1139-1156.

Votma A. 2011. Sharp 240 Watt 20 Volt Solar Panel, http://www.alibaba.com/product-free/114761829/Sharp_NU_U240F1_240_Watt_20.html (21 April 2011)

Wang, C., 2006. Modeling and control of hybrid Wind/photovoltaic/fuel cell distributed generation systems. *Ph.D dissertation, Montana state university, Bozeman, Montana.*

Wang, C. and Nehrir, M. 2007. Load transient mitigation for stand-alone fuel cell power generation systems. *IEEE Transactions on Energy Conversion,* **22(4):** 864-872.

Wichert, B. Dymond, M. Lawrance, W. and Friese, T. 2001. Development of a test facility for photovoltaic-diesel hybrid energy systems. *Renewable Energy,* **22:** 311-319.

Willis, H. L. and Scott, W. G. 2000. *Distributed power generation: planning and evaluation.* Marcel Dekker.

Woyte, A.Belmans, R. and Nijs, J. 2001. Grid-connected photovoltaic systems. *International Conference Power Generation and Sustainable Development-AIM, Liège, Belgium,* **4:**233-238.

Woyte, A.Belmans, R. and Njis, J. 2003. Testing the islanding protection function of photovoltaic inverters. *IEEE Power Engineering Society General Meeting,* **18:** 157-162.

Zaharim, A.Razali, A.Gim, T. and Sopian, K. 2009. Time series analysis of solar radiation data in the tropics. *European Journal of Scientific Research,* **25:** 672-678.

Zoumakis, N. 1993. The dependence of the power-law exponent on surface roughness and stability in a neutrally and stably stratified surface boundary layer. *Atmosfera,* **6:** 79-83.